HSD-TR-90-005

AD-A223 770

ASSESSMENT SYSTEM FOR AIRCRAFT NOISE (ASAN): DEVELOPMENT OF ALPHA-TEST PROTOTYPE SYSTEM SOFTWARE

Nicolaas H. Reddingius
John S. Smyth

BBN Systems and Technologies Corporation
21120 Vanowen Street
Canoga Park, CA 91303

February 1990

Final Report for Period October 1988 - November 1989

Approved for public release; distribution is unlimited.

Noise and Sonic Boom Impact Technology
Human Systems Division
Air Force Systems Command
Brooks Air Force Base, TX 78235-5000

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility nor any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise as in any manner construed, as licensing the holder, or any other person or corporation; or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed and is releasable to the National Technical Information Service (NTIS), where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

Preston S. Hall

PRESTON S. HALL
Deputy NSBIT Program Manager

DTIC COPY INSPECTED 6

Accesion For	
NTIS CRA&I	✓
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

FOR THE COMMANDER

Michael G MacNaughton

MICHAEL G. MACNAUGHTON, Col, USAF, BSC
Program Director
Human Systems

Please do not request copies of this report from the Human Systems Division. Copies may be obtained from DTIC. Address your request for additional copies to:

Defense Technical Information Center
Cameron Station
Alexandria VA 22304-6145

If your address has changed, if you wish to be removed from our mailing list, or if your organization no longer employs the addressee, please nofify HSD/XART, Brooks AFB TX 78235-5000 to help us maintain a current mailing list.

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): Report 7227, NSBIT Task Order 0014	5. MONITORING ORGANIZATION REPORT NUMBER(S): HSD-TR-90-005
6a. NAME OF PERFORMING ORGANIZATION: BBN Systems and Technologies Corporation; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: HSD/YAH (NSBIT)
6c. ADDRESS (City, State, and ZIP Code): 21120 Vanowen Street, Canoga Park, CA 91303	7b. ADDRESS (City, State, and ZIP Code): Wright-Patterson AFB OH 45433-6573
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Noise and Sonic Boom Impact Technology; 8b. OFFICE SYMBOL (If applicable): HSD/YAH (NSBIT)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F33615-86-C-0530
8c. ADDRESS (City, State, and ZIP Code): Wright-Patterson AFB OH 45433-6573	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 63723F; PROJECT NO. 3037; TASK NO 02; WORK UNIT ACCESSION NO. 02

11. TITLE (Include Security Classification) (U)
Assessment System for Aircraft Noise (ASAN): Development of Alpha-Test Prototype System Software

12. PERSONAL AUTHOR(S)
Reddingius, Nicolaas H. and Smyth, John S.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 88/10/11 TO 89/11/3[illegible]	1990 April 20	18

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	aircraft noise prediction, noise exposure maps, environmental planning, ASAN, GRASS, ORACLE
12	05.07		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This document describes the Alpha-Test version of the Assessment System for Aircraft Noise (ASAN). ASAN was developed for the United States Air Force's Noise and Sonic Boom Impact Technology Advanced Development Program Office (NSBIT ADPO).

The Purpose of ASAN is to provide Air Force route and environmental planners with a set tools for preparing the noise portion of environmental impact statements (EIS), environmental assessments (EA), and findings of no significant impact (FONSI). ASAN provides a consistent set of procedures and models which represent the current state-of-the-art in noise engineering practice.

This report contains a brief overview of the technical issues of developing the ASAN system. A User Manual which guides the environmental planner in the use of ASAN is available as a separate volume.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL: Robert Kull, Major, USAF	22b. TELEPHONE (Include Area Code): (513) 255-3376	22c. OFFICE SYMBOL: HSD/YAH (NSBIT)

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

TABLE OF CONTENTS

ACKNOWLEDGMENTS

Many people have contributed to making ASAN a reality. In the early days, now seemingly a distant memory, Sanford Fidell conceived the idea to organize the environmental planner's work around a geographic information system. Michael Harris, who since went on to other projects, ported his graphics and user interface expertise from UNIX to MS-DOS, for the first conceptual prototype. Linda Secrist Hutchings not only ported things back from MS-DOS to UNIX, but also contributed her sense of aesthetics to screen designs. Two more Michaels (Reaves and Malter) assisted the authors in completing the graphics and text capabilities. The largely thankless task of keeping this team of wildmen in line and coordinating our efforts with concurrent NSBIT sponsored research programs fell to Andrew Kugler, BBN program manager for this work. His vision for the future direction of ASAN became chapter 7 of this report. Messrs. Alton Chavis (TAC) and David Henney (SAC) shared the viewpoints of environmental planners with us, and made us aware of the vast differences in mission requirements among the major commands. Special appreciation is in order to Mr. Lawrence S. Finegold, Mr. P. Scott Hall and Maj. Robert Kull of NSBIT for their suggestions and, especially, for their understanding during the period when ASAN produced only core dumps and disk crashes.

ASSESSMENT SYSTEM FOR AIRCRAFT NOISE

DEVELOPMENT OF ALPHA-TEST PROTOTYPE SYSTEM SOFTWARE

1 EXECUTIVE SUMMARY

These reports describe the development of the Alpha-Test prototype system software of the Assessment System for Aircraft Noise (ASAN). ASAN was developed for the United States Air Force's (USAF) Noise and Sonic Boom Impact Technology Advanced Development Program Office (NSBIT ADPO).

The purpose of ASAN is to provide USAF route planners and environmental planners with a set of tools for preparing the noise portion of environmental impact statements (EIS), environmental assessments (EA), and findings of no significant impact (FONSI). ASAN provides these planners a consistent set of procedures and models which represent the current state of the art in noise engineering practice. While computer hardware is required to deliver this capability, ASAN development was strictly a software project.

Under a previous effort, a demonstration prototype had been developed, which showed the feasibility of performing these tasks on the desktop size microcomputer. Previously, mathematical models of noise produced by aircraft had required the services of large computers. The present effort implemented an actual functional prototype system, the Alpha-Test version.

Since the USAF DESKTOP III procurement, which will define the standard USAF Microcomputer technology for the next 3-5 years, had not been finalized by the time critical design decisions for ASAN had to be made, it was agreed to implement the system on the Zenith Z-386 personal computer (PC), which was being delivered to the USAF at that time, and to use the UNIX operating system. The basic philosophy behind hardware choices for the prototype development effort was to try to match the systems expected to be available under DESKTOP III.

Following current software engineering practice, ASAN is implemented on top of a number of fundamental building blocks: the ORACLE[1] data base manager, the GRASS[2], geographic information system (GIS), and the BBN User Interface System. The C language was chosen as the implementation language for maximum transportability across comparable hardware. The ORACLE database management system provides the sophisticated capabilities necessary for ASAN. This system is available for a wide variety of computer hardware and operating systems. While many graphics systems use special-purpose hardware, we used general purpose off-the-shelf hardware where possible.

---

1 ORACLE is a registered trademark of Oracle Corporation, Belmont, California.

2 Geographical Resource Analysis Support System, developed by the U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign, Illinois.

During the various phases of development we have been able to move away from rather esoteric (and expensive) graphics hardware on a personal computer advanced technology (PC-AT) to relatively standard Video Graphics Array (VGA) display technology on a 386 PC.

This report contains a brief overview of the technical issues of developing the ASAN system. A separate User Manual guides the planner through the various aspects of conducting an assessment using ASAN. A Programmer Manual, which discusses the data base tables and program code used in ASAN, is also available.

2 TECHNICAL OVERVIEW

ASAN is a computer system designed to assist USAF route planners and environmental planners in the preparation of EIS, EA, and FONSI. Specifically, ASAN calculates noise exposures predicted from a specification of missions flown and expected effects due to such exposures. In addition to providing the planner with extensive tools to obtain such exposures and effect predictions, ASAN has the capability to produce a standard set of tables and explanatory text with which to support an EIS, EA or FONSI.

The Alpha-Test Version of ASAN evolved from an earlier Demonstration Prototype. The Demonstration Prototype, delivered in 1988, was a preliminary version to assess the feasibility of building a system of this magnitude on a PC. The demonstration version made use of a Zenith Z-248 computer running under MS-DOS, (although some protected mode operations were involved), and required considerable special purpose graphics hardware. The Alpha-Test version runs on a Zenith Z-386 computer under the UNIX operating system and uses standard VGA display technology.

At the conclusion of the demonstration prototype version a number of recommendations were made as to the implementation of the Alpha-Test Version. Particularly of importance was the fact that the ASAN production system would be an operational system during the 1990s. During the 1990s we expect more powerful PCs than the Zenith Z-248 to be commonly available. Furthermore new operating systems, in addition to MS-DOS, will be available in the target period. Since MS-DOS imposed severe restrictions on the software--largely related to the design of the original 8086 and 8088 computer chips--it was felt that a move to UNIX would be more appropriate. UNIX operates as a full multi-tasking, multi-user operating system and, even if it were not the ultimate USAF choice for desktop operating systems, the features provided by UNIX would more or less correspond to those of any likely candidate operating system. This approach would keep all likely options open, while at the same time enabling further development of ASAN.

Since the design was to make ASAN highly portable, it appeared wise to proceed with UNIX and the C language, which are generally considered to be the most portable software platforms available. This approach made sense for other technical reasons as well. The MS-DOS operating system puts a limit on the amount of memory that an application can use. ASAN is a large enough program that these limits would be exceeded. There are techniques to "shoe horn" such programs into MS-DOS, but this is very labor intensive. It also makes the program totally dependent on MS-DOS and subsequent changes may require very time-consuming reengineering. ASAN, by its very nature, is an evolving set of tools; continued dependence on MS-DOS would make it a costly set to maintain.

The change to UNIX would be relatively straightforward. The GRASS GIS is a UNIX program to begin with, the BBN user interface is available under UNIX, and the ORACLE database manager would also become available under UNIX for desktop machines during the period of the contract. Thus, pending a decision on DESKTOP III by the USAF, UNIX appeared to be the logical choice. In October 1988 it was agreed that the Alpha-Test version of ASAN would be developed under UNIX on the PC 386.

Because of the uncertainty about the future operating system environment, it was decided to keep ASAN a relatively monolithic program as it had been under MS DOS. That is, all of ASAN is a single load module without any overlays. While it would be possible to optimize and modify the code to make it a more UNIX-dependent program (making better use of the facilities of the operating system, increasing modularity, running the program as a set of tasks connected by pipes as a common practice in UNIX), we chose to keep the basic structure untouched. Once a final decision is made on the operating system for ASAN, it is appropriate to revisit this design and modify it for the environment chosen.

The interaction with ORACLE follows the standard process of writing imbedded Structured Query Language (SQL) code in C language programs. These programs are first processed by the ORACLE preprocessor before being compiled as straight C programs. In this respect, the MS-DOS version and the UNIX version operated the same way. While in the demonstration version, several GRASS routines were ported to MS-DOS and severely modified in the process, we chose to keep the GRASS processes running as pure UNIX processes.

GRASS processes are spawned by the Alpha-Test version of ASAN as needed. The parent process always waits until the child process finishes. Communication between processes, when necessary, is through temporary files. No attempt has been made to use pipes between processes. Similarly UNIX interprocess communication is not implemented between ASAN and GRASS. Thus, we are able to take advantage of UNIX multitasking without making the code totally dependent on the UNIX environment.

3 HARDWARE CONSIDERATIONS

The implementation of ASAN was predicated on the availability of Zenith (or similar IBM PC-AT compatible) PC hardware. Initially the Zenith Z-248 was chosen since it was the standard microcomputer for the USAF. It became apparent after the demonstration version had been built that this machine with its 80286 central processing unit (CPU) would not be adequate to meet the needs of ASAN. The 80286 uses the segmented memory structure of the predecessor 8088 CPU. The MS-DOS C-compiler requires that all DGROUP memory fits into a single segment. The total requirements for such memory, which includes the description of the user dialogue screens and the database queries, exceeded the maximum segment size.

At about the same time Zenith started delivering Z-386 PCs to the USAF, and the decision was made to use this hardware platform for ASAN. The 80386 CPU can operate in page mode, supporting virtual memory management and demand paging. This capability enables a full implementation of UNIX System V--not the XENIX segmented memory variant--which removes the memory limits of the 80286 CPU and the MS-DOS C-compiler.

Table Hardware Configuration for ASAN Alpha-Test Version.

1. Zenith Z-386 with 4 MB RAM, 1.2 MB Floppy, one serial and one parallel port.
2. 300 MB ESDI Disk with Controller.
3. Intel 30387 16-MHz Math Co-processor
4. Everex Model EI 830-05 60 MB Cartridge Tape Drive.
5. Orchid Designer 800 VGA Card with 512 kB memory.
6. NEC Multisync II Monitor
7. Logitec 3-Button Bus Mouse
8. WYSE-50 or equivalent terminal.
9. Tektronics Model 4696 Printer.

The configuration required for ASAN (Table) is a 80386 PC with a math coprocessor (80387), an Orchid Designer 800 VGA[3] card and at least 4 MB of random access memory (RAM). Besides, to have sufficient disk space available for map imagery, the machines should be equipped with at least a 300 MB ESDI drive. Two Zenith computers were procured for the execution of this project.

[3] At present GRASS only works with this specific card. The Video Graphics Array (VGA) has rather tight tolerances, and undesirable interaction (e.g., preventing the machine from booting at all) sometimes results if either the VGA or any other hardware does not conform to specification.

After the work had been completed, the DESKTOP III procurement was awarded to Unisys. The new USAF standard microcomputer will be based on a 25-MHz Intel 80386 processor. Since compatibility with earlier machines was part of the DESKTOP III specification it is assumed that migrating ASAN from Zenith to Unisys hardware will not pose major problems.

4 SOFTWARE CONSIDERATIONS

The initial demonstration version of ASAN was developed for MS-DOS on a PC-AT equivalent machine. At the conclusion of this phase it became apparent that we would exceed the capability of the MS-DOS environment and the 80286 CPU if we continued to keep the ASAN program code totally machine independent. If we continued with PC hardware there were 2 clear alternatives. We could continue with the 80286/MS-DOS environment and make ASAN totally dependent on it, or we could keep the program independent but use the 80386/UNIX environment.

The former approach would lock ASAN, a system that will be operational in the 1990s, firmly into the technology of the 1970s. This action would make the program difficult to modify and maintain as well as expensive to build. The latter approach was more in line with the direction of DESKTOP-III and general trends in the (civilian) market and would also retain maximum flexibility in terms of hardware and minimize maintenance cost.

For maximum long-term compatibility Interactive Systems' UNIX V Release 3.2 was chosen. Release 3.2 is expected to remain a standard UNIX release for some time to come, certainly for the PC. Several major vendors in addition to Interactive Systems are in this market, Santa Cruz Operations (SCO) is, for example, planning to have it's XENIX product fully compatible with release 3.2 of UNIX at the binary level.

While the full development systems of both UNIX and ORACLE are required for ASAN development, the actual running version of ASAN only requires the run time packages of both, which brings the cost of the operating system and the database manager considerably down. Additionally, if the USAF wishes to release ASAN as a standard product throughout the USAF, it is possible to obtain volume licenses for such purposes, bringing the cost down even further.

5 MODELS USED

ASAN implements several standard practice engineering models. The exposure models used are ZROUTE, developed by Armstrong Aerospace Medical Research Laboratory (AAMRL) for military training routes (MTR), and the probability ellipse model, developed by Dr. W.J. Galloway of BBN for supersonic military operating areas (MOA). No models at present are incorporated for either supersonic MTRs or nonsupersonic air combat maneuvering operations in MOAs. On the effects side, no animal models were implemented since no such models are currently available. The human effects incorporated are human annoyance, human sleep interference, human hearing loss, and land use compatibility. A structural damage model for conventional structures due to sonic booms in supersonic MOAs developed under a separate effort was also implemented. ASAN has been designed to minimize the effort required to add other noise and effects models, as they are developed in the future.

5.1 The Military Training Route Model

The model for calculating the exposure of MTRs is an adaptation of AAMRL's ZROUTE program. This program was an interim program developed to provide environmental planners with side line estimates of noise from MTRs. This program was originally written in interactive BASIC, which we translated into the C language and turned into a subroutine callable from the main ASAN logic.

There are inherent limitations to this model. ZROUTE calculates strictly side line exposures from an MTR which is viewed by a ground observer as originating and terminating over the horizon. There are no provisions to account for curvature of the flight track turns, or exposure from more than one MTR at the same time. Thus, while ASAN will produce contours along the MTR, they will be inaccurate in the vicinity of navigation points. The model also does not provide for any change in altitude or power setting during the flight segment.

Neither rise and fall of the terrain with respect to the aircraft nor dispersion of the flight track or deviation from the nominal center line of the MTR are being accounted for in ZROUTE and therefore not in ASAN. The mechanism exists within ASAN to specify mission altitudes in feet above mean sea level (MSL) as well as above ground level (AGL), but at present reference to sea level is not functional since it requires an interface to a digital elevation map which is not yet available. Furthermore, such a map might imply that terrain is considered in the model, but this level of refinement does not exist in ZROUTE nor in its ROUTEMAP successor program.

MTR operations are specified in terms of missions and aircraft. Missions on an MTR are defined in terms of the navigation points flown, and the speed and altitude at which the aircraft flies. To complete the ZROUTE specification, for each aircraft flying that mission, the proper power setting needs to be specified. Thus, altitude and speed are a function of the mission only, whereas power management is a function of mission and aircraft together.

The mission specification includes the number of aircraft that normally fly together as a formation. This has a bearing on the single event level (SEL) associated with that mission. If two aircraft fly a particular mission, the SEL will therefore be 3dB higher than if a single aircraft were to fly this mission. The single event levels are used for such models as sleep awakening and hearing loss. In addition, the number of sorties on a month to month basis needs to be specified. For purposes of ASAN, daytime operations are those taking place from 0701 to 2200 hours, nighttime operations those from 2201 to 0700 hours.

5.2 The Military Operating Area Model

The model developed to calculate noise exposure and effects for operations in an MOA has been taken directly from the work of Galloway (1983). The statistical MOA model, which is based on Air Combat Maneuvering Instrumentation (ACMI) data at Luke Air Force Base, Arizona, has been included as a series of subroutines in the ASAN model.

MOA operations are specified in terms of a statistical distribution of supersonic events taking place in an area referred to as the "engagement zone," and a set of statistical data for specific aircraft maneuvering activity taking place within the engagement zone. The engagement zone can be described as an ellipse, within which the probability that a supersonic event occurs is greater than zero. The ellipse is described by a center position, an orientation for its semi-major axis (known as the "engagement axis"), plus the average ground level within the engagement zone.

Aircraft operations, taken from ACMI data, describe the following parameters: Root Mean Square (RMS) aircraft Mach number, RMS time of supersonic events within the engagement area, RMS number of events per aircraft sortie, and aircraft type, altitude, and pitch angle. These data are used to generate the probability of a supersonic event, the event overpressure, and the C-weighted single event level (CSEL) and C-weighted day-night averaged level (CDNL) at the point. ASAN also has the ability to create a noise contour map to display the CDNL levels over the entire engagement area.

The model is limited only by data collection and reduction delays. Both the probability model and the RMS aircraft profiles are generated from analyses of ACMI data tapes. At present, only one distribution, F-15 aircraft operations within the Sells MOA in Arizona, is available. While clearly representative of MOA operations it represents knowledge based on limited information. Little is understood about how differences in missions might affect parameters in the model. Until more of the ACMI data is reduced, not only for Luke AFB but also for many other MOAs, the model cannot be considered "complete."

5.3 Human Effects Models

Four human effects models have been included into ASAN. These models implement the current state of the art as it is practiced at the time of this writing. It does not include any of the concurrent research being sponsored by the NSBIT ADPO, or any Department of Defense, or other government sponsored programs.

5.3.1 Human Annoyance

Human annoyance is based on the 1989 revision (Fidell, et al., 1989) of the "Schultz curve" which relates the percentage highly annoyed to L_{dn} at a location. It is valid for L_{dn} levels exceeding 45 dB and is given by:

$$0.0360\ L_{dn}^2 - 3.2701\ L_{dn} + 79.1393. \tag{1}$$

5.3.2 Sleep Interference

The sleep interference module implements Lukas' equation:

$$\%\ \text{Awakened} = 1.1 * \text{ASEL} - 49.5 \tag{2}$$

The quantity ASEL, the interior sound exposure level, is calculated according to Environmental Protection Agency (EPA) guidelines which assume a transmission loss through a residence of 17 or 27 dB for the case of open and closed windows, respectively (Goldstein and Lukas, 1980).

ASAN calculates the number of awakenings for all events specified. Multi-ship sorties are counted as a single event, but one having an SEL which is 10 log(n) higher than for a single aircraft. Otherwise all events are considered totally independent; no provision is made for bunching of flights which is likely to occur for training missions. Awakenings are only computed for sites identified as having a "residential" or "hospital" attribute, and only consider operations between 2200-0700 hours.

5.3.3 Land Use Compatibility

The land use compatibility module implements a simplified version of the Air Installation Compatible Use Zone (AICUZ) and other USAF guidelines (USAF, 1984). The land use categories are consistent with American National Standards Institute Standard S3.23-1980. ASAN will print a table identifying the number of land uses considered acceptable, generally unacceptable, or unacceptable. The detailed ASAN report shows the particulars for each identified ground location.

5.3.4 Hearing Loss

The hearing loss module implements the concepts of the EPA Levels Document (EPA, 1974). It is assumed that people are exposed to the *outdoor* L_{eq} generated by flight operations. People exposed to L_{eq} in excess of 70 dBA are considered to be exposed to excessive noise.

5.4 Structural Damage

The current version of ASAN has no model to assess the effects of MTR activities upon structures located along the path of MTR operations. The only options available to the planner are the effects of MOA operations on structures located within the MOA engagement zone. Additionally, only effects from a single MOA mission, or all missions within the current MOA engagement zone are realizable. The ASAN model assumes that engagement zones are disjoint, i.e., one zone shares no common region with another engagement zone within the MOA. Haber (1989) describes the Hershey and Higgins model used to calculate the probability of damage to windows, plaster and bric-a-brac.

5.5 Incorporation of Future Models

Additional effects models will become available over time. The user dialogue screen already has provisions for several planned models. When a new model is developed these screen "buttons" can be activated to call a new computational model. The output of the model can be included as an additional screen showing the results of the analysis. Similarly an additional report function can be added to include the new analysis in the printed output.

All computations follow the same processing logic. For a specific source-receiver pair ASAN calculates a noise metric (SEL, L_{dn}, etc.) which describes this specific interaction. Contributions from all relevant sources are added to arrive at a total exposure. This value is then passed through a "filter," i.e. a function which transforms an exposure into an effect. For example, the Schultz curve is a filter which transforms L_{dn} into percent highly annoyed (%HA).

This result, perhaps applied to a receiver parameter, is then presented as output. For example, sonic boom strength is applied to a building's structural properties, such as number of windows, to predict glass breakage.

Mathematical models of this type naturally fit with ASAN's architecture. Even if the stimulus for an effect is not presently included in ASAN, the modifications are straightforward. The stimulus itself, e.g., L_{dn}, is the output of a (very complex) filter, which takes mission specifications, aircraft performance data, and geometric relations between sources and receivers as input to produce SEL, and from there ultimately L_{dn} as output. By keeping the filters independent from each other, one can add or remove them without affecting other parts of the program.

6 MAP DISPLAY AND ANALYSIS

To use all functions of ASAN, a PC with 2 video monitors is required. The color screen is used to display maps of noise levels and geographic information. A full geographic information system (GIS) drives this display. The capabilities of a GIS are far greater than those of a graphics program or even a computer aided design (CAD) system.

CAD systems were developed to automate the production of engineering drawings. A two-dimensional CAD system is usually built around a database of points, lines and arcs. A GIS requires that topological structure of the graphic representation also be included. For example, a GIS must insure that all polygons representing an area are closed *and remain so throughout all subsequent database updates.*

While a CAD system is designed to *manage the graphics image*, the GIS system is designed to *analyze the spatial relationships* among the elements. The GIS can, therefore, provide answers to questions such as, "what soil types occur within a mile of secondary roads and what is their relative abundance." Such queries require data structures not supported by CAD systems, although the purely graphical image of a map could be stored in either system.

The value of the GIS, therefore, is in the considerable mathematical machinery to transform various map projections, register satellite photographs on maps, and perform analyses on maps. The database to support such a system is of necessity much more complex than those used for a CAD system.

Thus, ASAN can not only show noise exposure or MTRs superposed on maps, but it can also answer questions such as: "how many square miles of the habitat of animal A is exposed to noise that exceeds level L." If the habitat map contains enough information, one can even calculate how many square miles (acres, hectare, etc.) are exposed to levels exceeding L, where animal A has a density of less than D per square mile, or the number of animals exposed to a given level.

Geographic Information Systems are, of course, themselves highly complex pieces of software, requiring considerable expertise to use them effectively. Mastering this complexity is unavoidable when one wants to create totally customized maps. ASAN can shield the user from much of this complexity by providing a set of tools that will allow him or her to manipulate "working drawing" quality images on the screen.

ASAN accomplishes this by using its own standard color assignment tables and keeping track of habitat classification codes internally. This allows ASAN to generate GIS command sequences to perform the most common analyses and create several standard displays automatically without the user having to know anything about the GIS itself.

ASAN presents a very complex geographic information system through an easy to use interface. This ease of use comes at a price: the capabilities of the system that are available to the user must remain limited to the most useful and most commonly used set. The full capabilities of GRASS, including the ability to make hard copy maps and perform very sophisticated analyses, are available to the user. Mastery of these features will, however, require the user to learn the intricacies of GRASS and becoming a seasoned GIS user.

7 SUMMARY AND RECOMMENDATIONS

The Alpha-Test version of ASAN gives the USAF a computer-based tool to predict noise exposure and to predict and assess environmental effects. While analytic and computer based tools for analyzing the noise exposure generated by MTR operations have been around for some time, ASAN is the first attempt to combine exposure from multiple MTRs and to do so with automatic consideration of MTR topology. ASAN also implements the first model for predicting sonic boom statistics for typical MOA operations. Finally, ASAN automates the process of assessing effects at many ground locations. This improves not only accuracy and consistency, but also allows cost-effective analysis of all important ground locations for many different scenarios. Finally, ASAN produces consistent and comprehensive documentation of the analyses performed.

With a basic capability now in place, the system is ready to be tested by a representative sample of USAF environmental planners and route planners (Alpha-Test Program). These people have provided important design contributions over the life of the development program. The Alpha-Test will be their first opportunity to actually use the system. During a week-long, hands-on test they will use the Alpha Version of ASAN to analyze environmental scenarios based on their current work.

We expect 2 results from this test process. The test process will lead to further refinement of the system, both in terms of capabilities and user interface, and it will provide planners with a basis to develop new standard procedures for the way their work is carried out. These 2 processes are, of course, interdependent. The current features of the system will suggest changes in procedure, while changes in procedure will suggest additional ASAN features.

Now that the feasibility of implementing this system on a PC has been shown, consideration must be given to building a production version of ASAN and the impact this will have on data gathering and analysis. The award of the DESKTOP III procurement will lead to further decisions on hardware and operating systems and ASAN will have to be brought into conformity with this new environment and restructured to give the best performance.

Depending on the results of the Alpha-Test, the enhancements envisioned for ASAN fall into 5 general categories:

1) **NOISE PREDICTIVE MODULES.** The current version of ASAN uses the ZROUTE model to predict subsonic noise along an MTR. An improved capability, called ROUTEMAP, is currently available and should replace ZROUTE in the Beta version. The capability to model "race track" patterns as part of a low-level MTR should also be investigated.

   While the main emphasis of subsonic noise predictions is associated with low-altitude MTRs, concern for environments in subsonic MOAs where air combat maneuvering is performed at low altitudes has also been raised. To develop a model for this application, ACMI data for such scenarios would have to be analyzed and a model similar to the sonic boom prediction model for a supersonic MOA developed for inclusion into ASAN.

A program designed to measure the sonic boom environment at the White Sands Missile Range, New Mexico, is in its final stage of completion. This program will result in a better understanding of the statistical distributions of supersonic events in an MOA and how they change as a function of airspace constraints and mission type. As a result, an upgraded model or models, which may be specific to each supersonic MOA airspace, may be included into ASAN.

2) **NOISE EFFECT PREDICTIVE MODULES.** Other projects under the NSBIT program are in the process of developing improved or new predictive models on the effect of aircraft noise and sonic booms on humans, animals and structures.

Preliminary animal models on the effect of subsonic noise on raptors and domestic animals are near completion and ready for inclusion into ASAN. These 2 models represent the first such capability on animal effects and are based entirely on sparse, existing research data.

Field research designed to add to and improve the state of the art in both wildlife and domestic animal effects is currently underway. In the wildlife area, research on ungulates (Caribou and Bighorn sheep) and raptors (*falconiformes*) are under way. In the domestic animal area, tests on large animals (milking cows, pregnant mares) and fowl (Turkey) are either under way or in the planning stages. The results of this research should be incorporated into the Beta-Test Version as they become available.

Research on the effect of subsonic noise and sonic booms on humans is also under way under the NSBIT program. A theory for predicting human annoyance has been developed and partially validated in the laboratory. Once this model is validated in the field, it should be included into ASAN. Research on sleep interference, specifically associated with describing the effect of noise on low density populations in the presence of low ambient noise, is currently planned. Both of these research areas will contribute improved predictive models during the life of the NSBIT program.

Research in the area of low frequency subsonic noise and sonic boom effects on structures will continue. A model for unconventional structures, which is under development, will augment the model for conventional structures. Field validation of these models are planned as are field studies of the cumulative damage from repeated sonic booms. The potential for structural effects due to energy from sonic booms propagating through the ground (sonic boom coupled Rayleigh waves) will be evaluated, as will the potential of precipitating avalanches and landslides by sonic booms. Finally, the rattling of structural elements and its effect on human annoyance will be addressed.

3) **MANAGEMENT OF THE GEO-DATABASE.** The current version of ASAN does not provide the tools needed to enter and manage standard geographic information, (topology, elevation, etc.). The inclusion of this capability is the highest priority in the future

development of ASAN and must be completed before this tool is fielded to the environmental community (Beta Version).

4) **ADDITIONAL REPORT GENERATION CAPABILITIES.** The current ASAN report structure allows for the computation and summary of noise effects either at individual locations or for the whole assessment. Additional capabilities should be defined in consultation with USAF route and environmental planners. A first step in this process is the Alpha-Test program. At this time, a capability to report summaries on a subarea basis has been identified as a needed feature. Subarea reports refer to summaries that include only a portion of the area affected by the assessment. For example, the number of people highly annoyed in each county along the MTR route.

5) **ASAN DATABASE.** The current version of ASAN contains limited geographic data. Some information about the Sells MOA airspace, land uses in its vicinity and cultural features have been entered. These data were included for demonstration purposes and no particular attention was paid to their accuracy. Similarly, the missions and operations in the database are illustrative only and in no way represent the actual use of the air space.

   Some portions of the database could be developed and distributed centrally, e.g., current MTRs, topology of MOAs and Weapon Ranges, state and county boundaries, major geographic features. Other types of databases, which might be distributed centrally, but which will probably be developed locally are, for example, location and description of individual structures along an MTR, animal habitats and migratory schedules. It is recommended that the USAF decide how extensive a database should be provided with the field version, if any at all, and, if so, that a plan be prepared for constructing at least the centrally developed portion of the database.

REFERENCES

Departments of the Air Force, the Army, and the Navy (June 1978). "Environmental Protection, Planning the Noise Environment" (AFM 19-10, TM 5-803-2, NAVPAC P-970).

U. S. Air Force (March 1984), "Assessing Noise Impact of Air Force Flying Operations: Guidelines," HQ USAF/LEEVX.

Environmental Protection Agency (1974), "Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety," EPA Report 550/9-74-0004.

Fidell, S., Barber, D., & Schultz, T.J. (1989). "Revision of a Dosage - Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise," U.S. Air Force Human Systems Division, Report HSD-TR-89-009.

Galloway, W.J. (1983). "Studies to Improve Environmental Assessments of Sonic Booms Produced During Air Combat Maneuvering," U.S. Air Force, Aerospace Medical Research Laboratory, Report AF-AMRL-TR-83-078.

Goldstein, J., & Lukas, J. (1980). "Noise and Sleep: Information Needs for Noise Control," *Noise as a Public Health Problem; Proceedings of the Third International Congress,* ASHA Reports No. 10, pp.442-448.

Haber, J.M. & Nakaki, D. (1989). "*Sonic Boom Damage to Conventional Structures*," U.S. Air Force Human Systems Division, Report HSD-TR-89-001.

Reddingius, N.H. and Smyth, J.S. (1990). "Assessment System for Aircraft Noise (ASAN): Alpha Test Software User Manual," Human Systems Division, Report (In press).